HI-SHEAR CORPORATION

ORDNANCE DIVISION

SUMMARY REPORT

EBW PRESSURE CARTRIDGE

25 JULY 1968

NASA CONTRACT NAS 8-20724

ORDNANCE DIVISION

2600 WEST 247TH STREET TORRANCE, CALIFORNIA 90509

hi-shear CORPORATION / ORDNANCE DIVISION

TORRANCE · CALIFORNIA

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Approved by: L. R. Gratt

Submitted by: B. Karp for R. Rynch

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ABSTRACT

This report summarizes the work performed during Phase I - Preliminary Design, Phase II - Prototype Design and the work performed to date in Phase III - Development of the NASA EBW Pressure Cartridge.

Phase I consisted of an investigation of the technical data to determine the most promising materials and design for the pressure cartridge. The prototype design was established in Phase II and tests performed to substantiate the design. The actual fabrication of cartridges is taking place during Phase III. The devices manufactured during Phase III will be used to perform a development test to assure the pressure cartridge meets the design specifications.

Work to be performed beyond this period is Phase IV - Qualification. This phase consists of manufacture of 200 cartridges plus 20 cartridges for acceptance tests. These units will be used by NASA in a test program to qualify the cartridge for space use.

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1.0 INTRODUCTION

Hi-Shear Corporation/Ordnance Division has been contracted by NASA to design, develop, fabricate and perform development tests on an Exploding Bridgewire (EBW) Pressure Cartridge. The program is divided into four phases. These are as follows:

Phase I Preliminary Design and Material Study

Investigation and evaluation of ordnance materials and preliminary design of EBW Pressure Cartridge.

Phase II Prototype Design

Establish prototype design and testing of candidate ordnance materials.

Phase III Development Test and Final Design

Fabricate cartridges and perform Development Test Program.

Phase IV Qualification Program

Fabricate cartridges for Qualification Test Program.

2.0 PHASE I - PRELIMINARY DESIGN AND MATERIAL STUDY

The design as originated in the proposal was modified to include the latest innovations to provide the optimum device for meeting the NASA specifications. It consisted of a header assembly and charge assembly separately fabricated and welded together to form the total initiator.

2.1 HEADER ASSEMBLY

The header is made up of a ceramic insulator brazed into an inconel body. The electrical pins are brazed into the insulator prior to the body braze, but at a much higher temperature. This allows for the body braze to take place without affecting the seal characteristics of the electrical pin braze. The pins consist of three parts fabricated of stainless steel, molybdenum and nickel. The molybdenum portion is sandwiched between the stainless steel and nickel parts, and because of its coefficient of expansion maintains the ceramic insulator in a compressive stress at the operating temperatures of the cartridge. The nickel provides a good bonding medium for bridgewire attachment.

2.2 CHARGE BODY ASSEMBLY

The charge body material is also inconel. It provides the container for the main output charge. The size of the charge is dependent upon the output required. The specification calls for a capability of providing any output from 500 psig to 2000 psig in a 22cc bomb.

2.3 SAFETY GAP ASSEMBLY

The safety gap assembly is fabricated as a separate item and threaded into the header assembly after checkout. The design of the gap is coaxial with a ceramic insulator between the electrodes. The gap is inherently stable with a comparatively low impulse ratio due to injection of free electrons into the gap area from the ceramic/metal junction when a potential is impressed across the electrodes. The electrons are freed as a result of a high field intensity at the junction of the high dielectric ceramic insulation and the low dielectric anode material.

2.4 MATERIAL STUDY

A study of explosive and pyrotechnic materials was conducted to determine suitability in the EBW Pressure Cartridge.

The explosive materials considered for use as the priming charge included PETN, RDX, HNAB and HNS. There is previous history in the use of PETN and HNAB in slurry form as a prime charge in an EBW initiator configuration. The PETN slurry device was developed for use on the Polaris A3 system. It proved very successful for that application, but could not be adapted to the NASA EBW Pressure Cartridge mainly due to the temperature requirements of -319°F to +392°F.

Tests have been performed by Lockheed Missiles and Space Co. to determine the feasibility of using HNAB in slurry form as a prime charge. Results indicated functioning, no-fire and output characteristics are similar to PETN. In addition, HNAB is higher temperature resistant with a melting point of 220°C as opposed to PETN at 130°C and RDX at 208°C. Vacuum stability testing performed at 150°C and 1.0 mm Hg resulted in 1.8 ml/gm for RDX and only .08 ml/gm for HNAB after 48 hours.

The explosive HNS was dropped from consideration due to the difficulty associated with functioning at levels of energy available from the specified firing unit. The NASA specification was reviewed to determine the best combination of fuel, oxidizer and binder to be used for the EBW Pressure Cartridge. A study of materials available resulted in the recommended use of Zirconium or Titanium Hydride combined with Potassium Perchlorate with a fluorocarbon binder.

3.0 PHASE II - PROTOTYPE DESIGN

Testing of the various materials and configurations was initiated in Phase II. The following is the test program for the prototype testing.

PHASE II TEST PROGRAM

HIGH EXPLOSIVE TESTS

a. High explosive/binder configurations

b. Prime charge load

c. High explosive characteristics: Autoignition, Temperature-Altitude Stability, Thermal Cycling, Impact Sensitivity

ELECTROEXPLOSIVE INTERFACE

a. Bridgewire configuration

b. Electroexplosive sensitivity

3.1 PRIME CHARGE

The primer charge combination of materials best suited for the specification requirements was found to be HNAB/Viton A-HV/methyl ethyl ketone. This binder and solvent had less effect on the explosive than any other considered. The percentages of explosive and binder in the slurry were selected at 96/4, 90/10 and 85/15 on the basis of previous work performed by Lockheed. The 85% HNAB, 15% Viton combination was difficult to maintain without the HNAB settling in solution. This resulted in poorer adhesion and strength characteristics in comparison to the other two and was dropped from further study. Figure 1 shows test headers with the HNAB/Viton A-HV bead over the bridgewire.

After experimenting with a number of firings of the explosive/pyrotechnic combinations during early October, two groups of headers were fabricated as follows:

(1) Explosive: 3-8 mg - 96% HNAB, 4% Viton A-HV
Pyrotechnic: 120 mg - Zirconium, Potassium Perchlorate, Viton B.

(2) Explosive: 3-8 mg - 90% HNAB, 10% Viton A-HV
Pyrotechnic: 120 mg - Zirconium, Potassium Perchlorate Viton B.

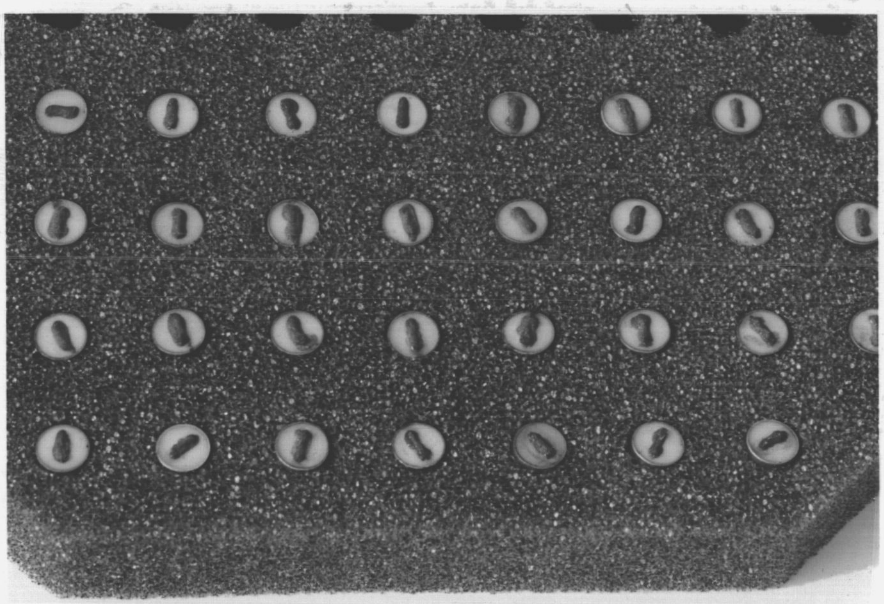


FIGURE 1

Bruceton Analyses were conducted and the data shown in Figures 2A and B. As can be seen, the variation in the 4% group was much less than in the 10% group. This wide tolerance may also be attributable to the settling of HNAB in solution with the binder.

In addition to the Bruceton Analyses conducted, two units from each group above were subjected to 220VAC to determine susceptibility without safety gap installation. In all cases the units functioned.

As a result of the tests conducted, the prime charge/main charge materials were selected and the next test sequence would be used to optimize the bridgewire parameters and prime charge load. In extensive testing with HNAB, Lockheed had determined the optimum bridgewire to be 2.7 mil diameter Neyoro G approximately .050 to .060 in length.

BRUCETON ANALYSIS

V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1300																				
1250																				
1200																				
1150																				
1100											X									
1050								X		O		X								
1000	X						O		O				X		X				X	
950		X		X		O								O		X		O		O
900			O		O												O			
850																				
800																				

X - Fire O - No Fire

Threshold -	980 volts
All Fire, .999 @ 90% Confidence Level	1454 volts
No-Fire, .999 @ 90% Confidence Level	506 volts

Date: 10-24-67

Explosive: 3-8 mg., 96% HNAB, 4% Viton A-HV

Bridgewire: 2.7 mil Neyoro G, .055 length

Main Charge: 120 mg Zirconium/Potassium Perchlorate

Firing Unit: HE - 001, S/N 001, 1.0 microfarad capacitor

Cable: 4 feet coaxial

Meter: Triplett Model 630-NS VOM

FIGURE 2A

BRUCETON ANALYSIS

V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1300																				
1250						X		X												
1200					O		O		X				X							
1150				O						X		O		X						
1100			O								O				X					
1050		O														X				X
1000	O																X		O	
950																		O		
900																				
850																				
800																				

X - Fire   O - No-Fire

Threshold -	1115 volts
All Fire, .999 @ 90% Confidence Level	2907 volts
No-Fire, .999 @ 90% Confidence Level	negative value

Date: 10-24-67

Explosive: 3-8 mg. 90% HNAB 10% Viton A-HV

Bridgewire: 2.7 mil. Neyoro G, .055 length

Main Charge: 120 mg. Zirconium/Potassium Perchlorate

Firing Unit: HE-001, S/N 001 1.0 microfarad capacitor

Cable: 4 feet coaxial

Meter: Triplett Model 630-NS VOM

FIGURE 2B

3.2 ELECTROEXPLOSIVE INTERFACE

Three groups of thirty units each were fabricated to perform Bruceton Analyses. These groups consisted of the following:

(1) Bridgewire: 2.7 mil diameter Neyoro G, .055 long
    Explosive: 4.87 mg sample average, 96% HNAB, 4% Viton
    Pyrotechnic: 200 mg. Zirconium, Potassium Perchlorate, Viton B

(2) Bridgewire: 2.7 mil diameter Neyoro G, .055 long
    Explosive: 15.38 mg sample average, 96% HNAB, 4% Viton B
    Pyrotechnic: 200 mg. Zirconium, Potassium Perchlorate, Viton B

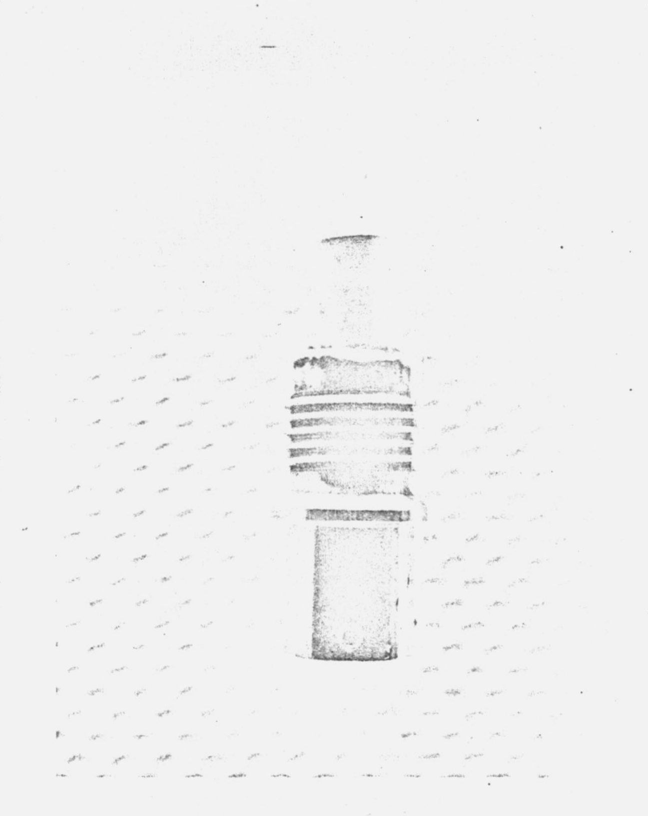
(3) Bridgewire: 2.7 mil diameter Neyoro G, .145 long
    Explosive: 20.47 mg. sample average, 96% HNAB, 4% Viton B
    Pyrotechnic: 200 mg. Zirconium, Potassium Perchlorate, Viton B

The data and results are shown in Figures 3A and B, C. The data from the first group did not appear as consistent as the previous test so a check was made of the test equipment. It was found that the voltage meter used had a tendency to stick thereby giving false readings. This meter was replaced for the subsequent tests.

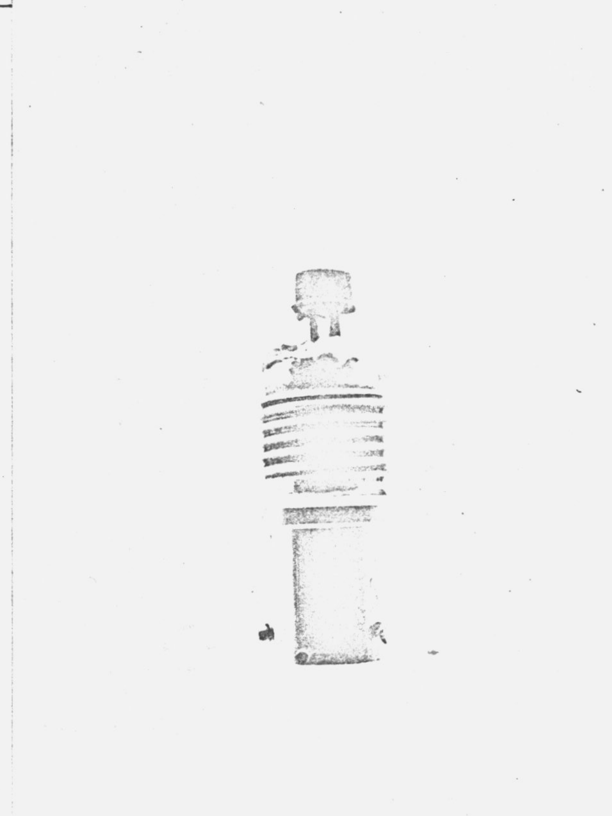
In any event, the intent of this portion of the test program was to determine the best electroexplosive interface and this was accomplished by the analyses performed. The group appears to best meet the requirements of the specification. Subsequent Bruceton and Probit Analyses will be conducted to determine actual all-fire and no-fire levels of the selected electroexplosive interface as provided in the actual configuration.

3.3 THERMAL CYCLING

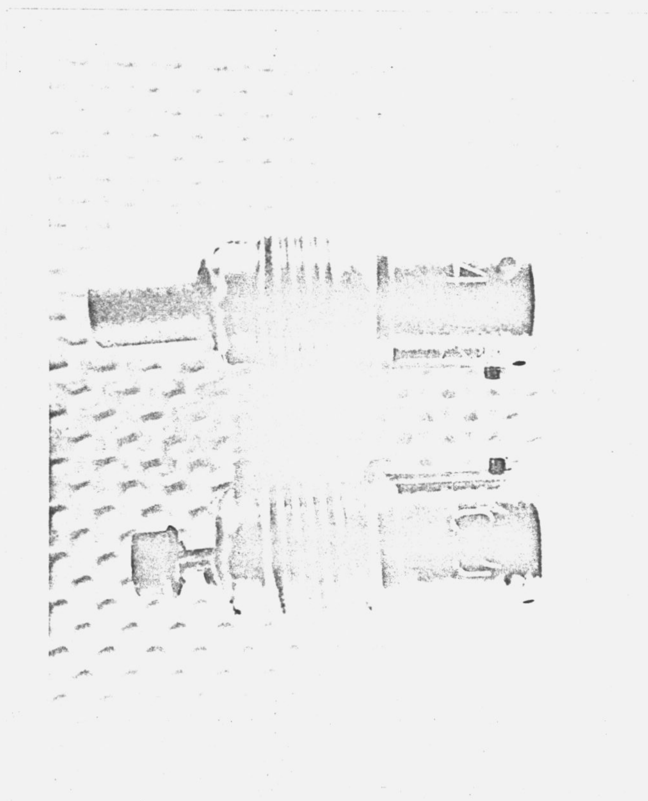
As the foregoing testing was being performed, another group of 6 units were fabricated for thermal cycling. Figure 4 shows this test unit before and after functioning. The test unit was soldered to an experimental cartridge body to allow it to be threaded into the 22.0 cc pressure bomb. The unit was loaded with 8 mg. of HNAB slurry and 50 mg of Zirconium/Potassium Perchlorate. The test sequence, instrumentation and results are shown in Appendix A. It may be concluded from this test that thermal cycling and functioning at the extreme temperatures will not



Before Functioning



After Functioning



EBW Pressure Cartridge

Connected to

Experimental Cartridge Body

FIGURE 4

prevent the EBW Pressure Cartridge from meeting the performance requirements of the specification.

3.4 HIGH EXPLOSIVE

A sample of HNAB was delivered to Truesdail Laboratories, Los Angeles for a determination of melting point. The results extended over the range of 213°C to 223°C, which are similar to the Lockheed reported data. A vacuum stability test of a sample of HNAB was performed at 150°C and a pressure of 5 mm Hg. The results were as follows:

24 hours - .093 cc/gm.

48 hours - .104 cc/gm.

This data also verifies the results published by Lockheed considering the tolerance limits of the test equipment used.

3.5 OUTPUT

At the request of NASA a test was performed to determine whether 3000psig could be realized in a 22 cc pressure bomb from the volume available in the charge body for the pyrotechnic load. In three tests performed, pressures of 3,200 psig. 3,300 psig and 3,300 psig were measured from a pyrotechnic load consisting of 60 mg of Zirconium/Potassium Perchlorate and 1100 mg. of Titanium Hydride/Potassium Perchlorate.

3.6 CONNECTOR INTERFACE

A high voltage test was performed on the connector interface of a unit similar to the NASA EBW Pressure Cartridge design. The test was performed at a pressure of 1.0 mm Hg. Voltage standoff from pin to pin exceeded 5,000 volts, and from pin to case, 2,000 volts.

4.0 PHASE III - DEVELOPMENT TEST AND FINAL DESIGN

The fabrication of prototype design hardware was initiated in Phase III. In addition the Development Test Program was established and is shown in Figure 5.

Experimental headers and cartridges were used to perform safety tests, conduct Bruceton Analyses and develop output charge loads. A group of headers were fabricated with single and multiple piece pins to test for comparative seal strength characteristics.

4.1 ELECTROEXPLOSIVE TESTS

The safety tests performed to date consisted of no-fire current, no-fire power and 5000 VDC capacitor discharge. Five experimental headers were subjected to a constant current of 1.0 ampere for 5 minutes; none functioned. These same units were then subjected to 3.5 amperes constant current for 5 minutes. In all cases the bridgewire burned out in the latter

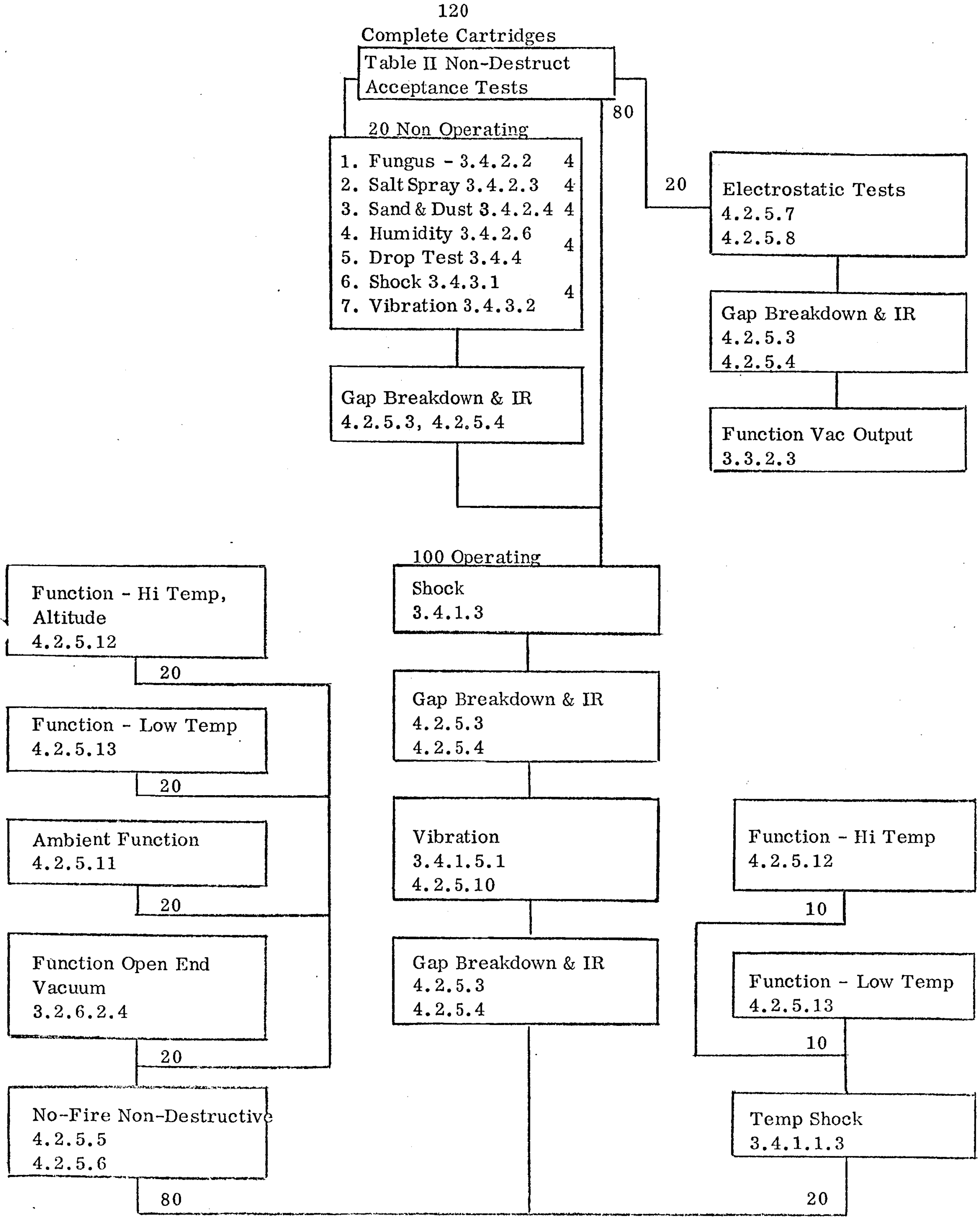

120
Complete Cartridges
Table II Non-Destruct
Acceptance Tests
80
20 Non Operating
1. Fungus - 3.4.2.2 4
2. Salt Spray 3.4.2.3 4
3. Sand & Dust 3.4.2.4 4
4. Humidity 3.4.2.6
5. Drop Test 3.4.4 4
6. Shock 3.4.3.1
7. Vibration 3.4.3.2 4
Gap Breakdown & IR
4.2.5.3, 4.2.5.4
20
Electrostatic Tests
4.2.5.7
4.2.5.8
Gap Breakdown & IR
4.2.5.3
4.2.5.4
Function Vac Output
3.3.2.3
100 Operating
Shock
3.4.1.3
Gap Breakdown & IR
4.2.5.3
4.2.5.4
Vibration
3.4.1.5.1
4.2.5.10
Gap Breakdown & IR
4.2.5.3
4.2.5.4
Function - Hi Temp, Altitude
4.2.5.12
20
Function - Low Temp
4.2.5.13
20
Ambient Function
4.2.5.11
20
Function Open End Vacuum
3.2.6.2.4
20
No-Fire Non-Destructive
4.2.5.5
4.2.5.6
80
Function - Hi Temp
4.2.5.12
10
Function - Low Temp
4.2.5.13
10
Temp Shock
3.4.1.1.3
20

FIGURE 5

test without any functioning occurring. Ten experimental headers were subjected to the discharge of a 1.5 microfarad capacitor charged to 500 VDC. In no case did any unit function or in any way distort the external configuration of the header. The discharge did affect the bridgewire circuit such that the header was rendered inoperative to a standard firing unit pulse.

Experimental headers were assembled with smaller diameter bridgewires as well as the selected 2.7 mil Neyoro G to determine whether susceptibility to 115 VAC could be improved without grossly affecting reliable functioning. Bruceton Analyses were conducted and the data shown in Figures 6A, B and C. In addition, 115 VAC no-fire tests were performed with the following results.

BRIDGEWIRE	RESULTS
2.7 mil Neyoro G	One of one functioned
2.0 mil Neyoro G	One of one functioned
1.5 mil Neyoro G	One of three functioned
1.5 mil Gold	One of two functioned

BRUCETON ANALYSES

V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1350															
1300														X	
1250											X		O		X
1200		X		X				X		O		O			
1150			O		X		O		O						
1100	O					O									

X = FIRE O = NO FIRE

Threshold:	1195 volts
All fire, .999 @ 90% Confidence Level:	1661 volts
No fire, .999 @ 90% Confidence Level:	729 volts

NOTES:
Date: 4/1/68
Bridgewire: 2.7 mil Neyoro G, .055 length
Explosive: 5.1 to 11.6 mg 96% HNAB, 4% Viton A-HV
Main Charge: 100 mg Zirconium/Potassium Perchlorate
Firing Unit: HE 001, S/N 001, 1.0 microfarad capacitor
Cable: 4 feet coaxial
Meter: Triplett Model 630 NS VOM

FIGURE 6A

BRUCETON ANALYSES

V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1450													X		O
1400												O		O	
1350											O				
1300	X							X		O					
1250			X		X		O		O						
1200		O		O		O									

X = FIRE   O = NO FIRE

Threshold:	1308 volts
All fire, .999 @ 90% Confidence Level:	3123 volts
No fire, .999 @ 90% Confidence Level:	Negative value.

NOTES:

Same as above except for following: Bridgewire: 2.0 mil Neyoro G, .055 length.
Explosive: 3.4 to 6.9 mg

FIGURE 6B

BRUCETON ANALYSIS

V	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1200														
1150					X		X							
1100	X			O		O		X						
1050			O						X				X	
1000		O								X		O		X
950											O			

X = FIRE **O = NO FIRE**

Threshold:	1059 volts
All fire, .999 @ 90% Confidence Level:	1904 volts
No fire, .999 @ 90% Confidence Level:	214 volts

NOTES:

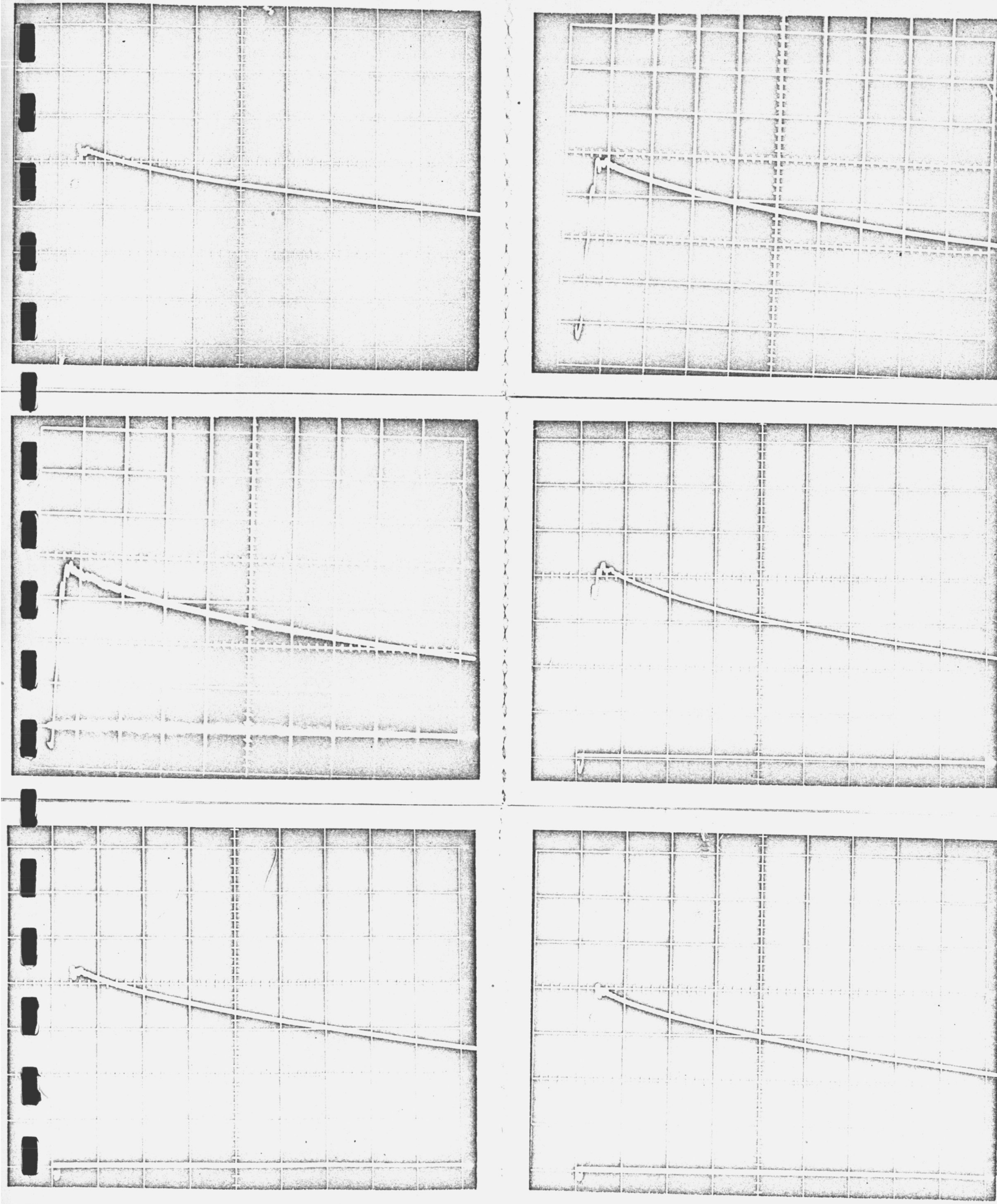
Same as above except for following: Bridgewire: 1.5 mil Neyoro G, .055 length
Explosive: 5.1 to 8.5 mg.

FIGURE 6C

Although there appears to be some gain in safety by reducing the bridgewire diameter, the sample size and gain realized does not appear to be sufficient to change the electroexplosive interface from that selected on the basis of the larger sample testing previously performed by Lockheed. The results of the Bruceton Analyses indicated that wire diameter did not substantially differ the threshold from one group to the others, but it was significant that the 2.7 mil bridgewire data did achieve the no-fire and all-fire requirements of the specification while the others did not due to their wider variations.

4.2 OUTPUT

Direction was received from NASA to manufacture the pressure cartridge so as to provide an output of 1,300 psig ± 20% in a 22.0 cc pressure bomb. Two groups of simulated cartridges were loaded with output charges of 485 mg. and 500 mg. respectively of Zirconium/Potassium Perchlorate handpressed over the HNAB prime charge and functioned in a 22.0 cc pressure bomb. The results as shown in Figures 7 and 8 vary from 1050 psi to 1350 psi. These are all within the specified tolerance, but required better charge load process control for less variation. Two additional groups of cartridges were loaded as before with 500 mg of Zirconium/Potassium Perchlorate as



EBW PRESSURE CARTRIDGE OUTPUT TEST
PRESSURE - 300 psi/cm TIME - 1 MS/CM 5-3-68

FIGURE 7

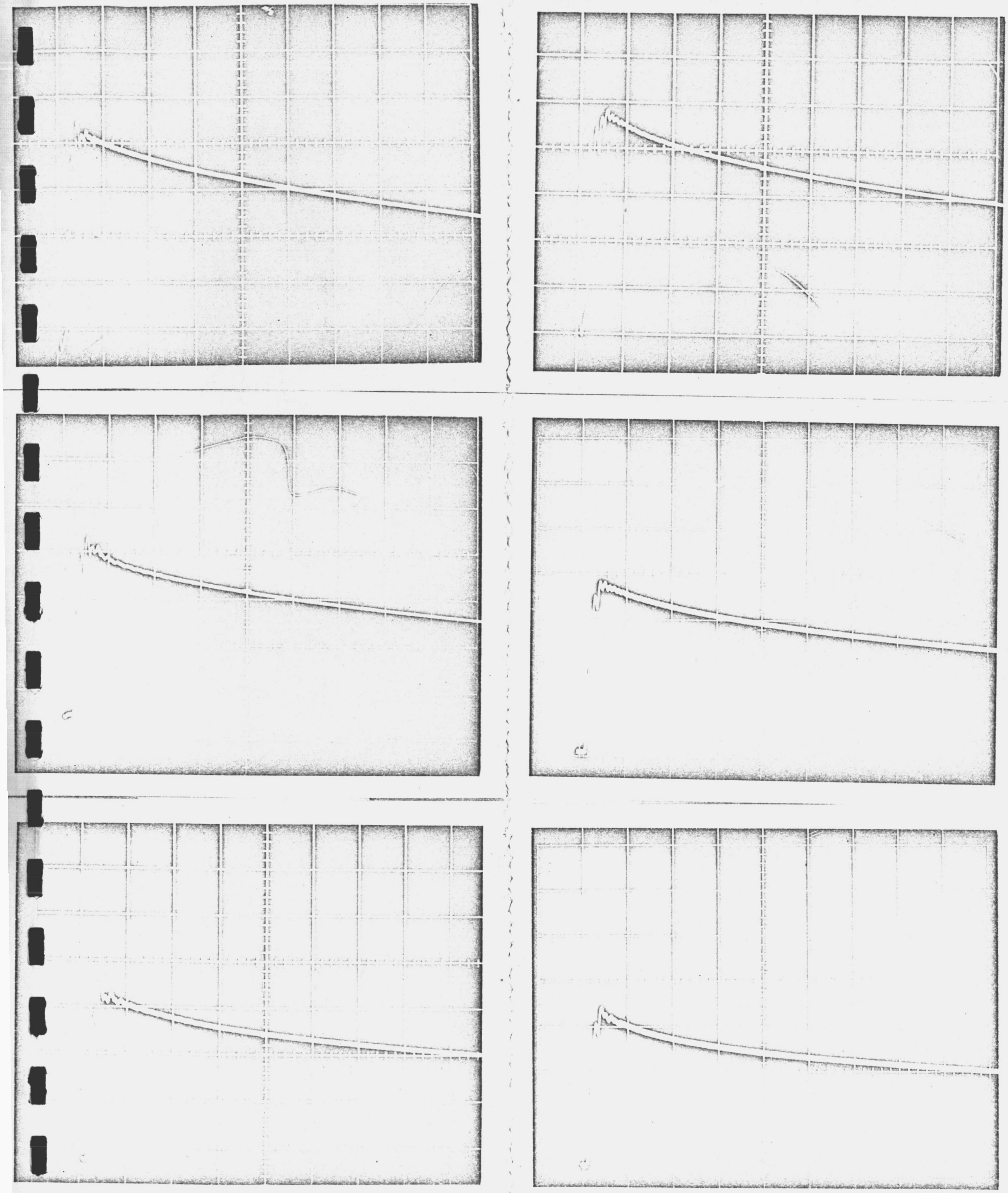


FIGURE 8

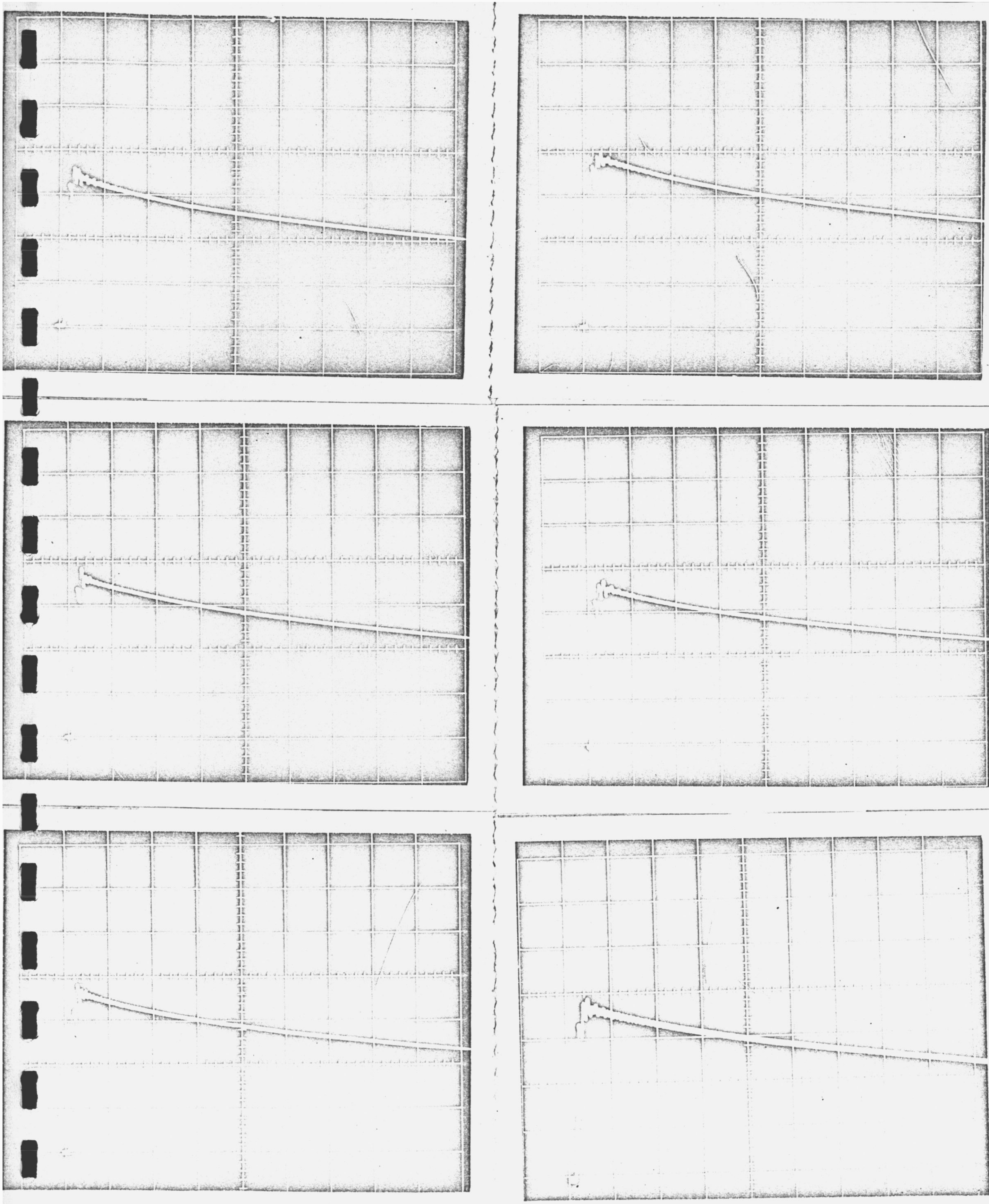
5-8-68

the output charge, but in this instance the charge was pressed in the bodies at 5,000 psi. The results of these units functioned in a 22.0 cc pressure bomb are shown in Figures 9 and 10. This data shows a variation of only 70 psig from the maximum pressure to the minimum pressure recorded, the high being 1,330 psig and the low 1,260 psig.

4.3 PIN SEAL STRENGTH TEST

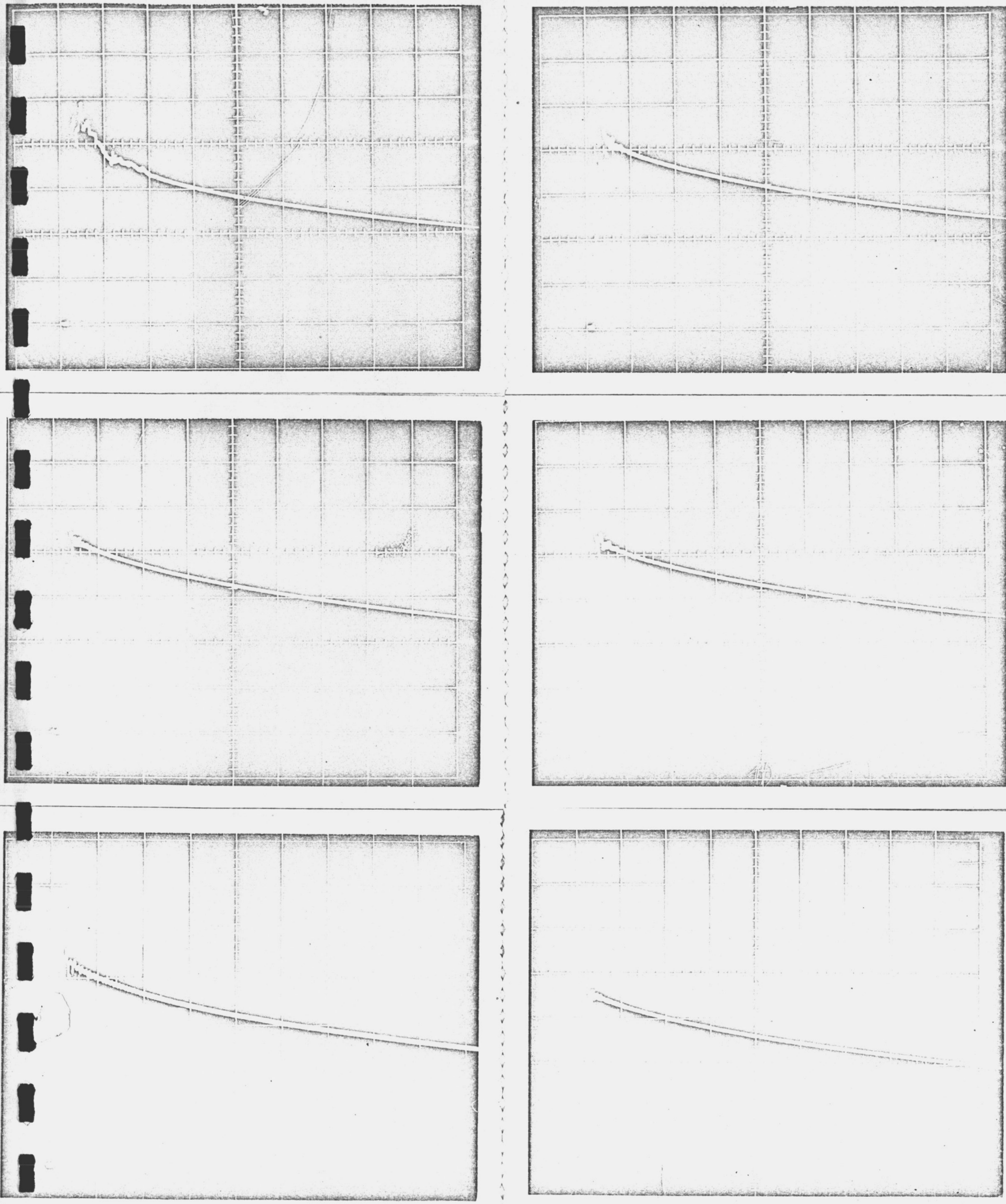
A special test was performed to determine the comparative seal strength characteristics of headers with multiple piece pins (Figure 11) versus single piece pins. The first test consisted of five pressure cycles to 5,400 psig of nitrogen gas for 1 minute, thermal shock by one hour immersion in liquid nitrogen then one hour in a 400°F oven, and finally five additional pressure cycles to 5,400 psig for 1 minute at ambient temperature. There were seven headers tested, four of the single piece pin and three of the multiple piece pin. The only failure noted was leakage around the long pin area of one of the single piece pin headers at the first pressure cycle after thermal shock. Figure 12 shows the area of leakage.

The six remaining headers from the above test, three of each type, were subjected to an explosive shock and then pressure cycles to 5,400 psi for 1 minute at ambient temperature . The



EBW PRESSURE CARTRIDGE OUTPUT TEST
Pressure 300 PSI/cm   Time 1 ms/cm 6/3/68

FIGURE 9



EBW PRESSURE CARTRIDGE OUTPUT TEST
Pressure 300 PSI/cm Time 1 ms/cm 5/27/68

FIGURE 10

explosive charge consisted of 35 mg of PETN initiated by an exploding bridgewire. After functioning the headers were pressure checked in sequence on the face as shown in Figure 13 A, B and C. The results were as follows:

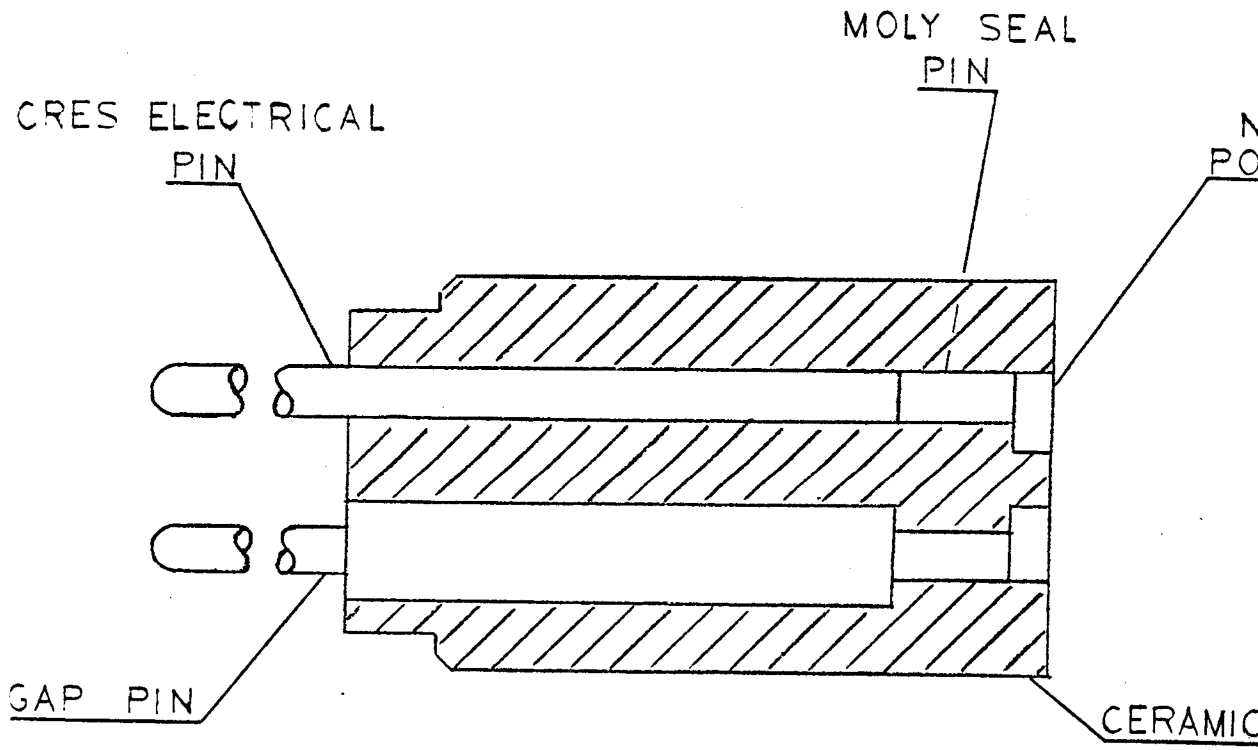
a. No units leaked

b. One multiple pin header and all three single pin headers leaked.

c. One of the single pin headers from test b above did not leak. All other units remained the same.

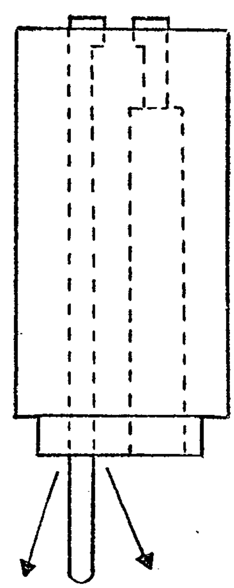
The leaks that did occur were considered minute.

One of the main problems encountered in fabricating the headers was alignment of the single piece pin with the hole and countersink in the ceramic. Tolerance buildup caused selection of parts on an individual basis. At least one third of the pins and ceramic bodies could not be made to fit. This condition did not exist with the multiple piece pins due to the dependency of the electrical and seal pins only to the hole and the post only to the countersink. This may be better seen by comparing the multiple pin header as shown in Figure 11 with the single pin header shown in Figure 12. The countersink is a grinding operation



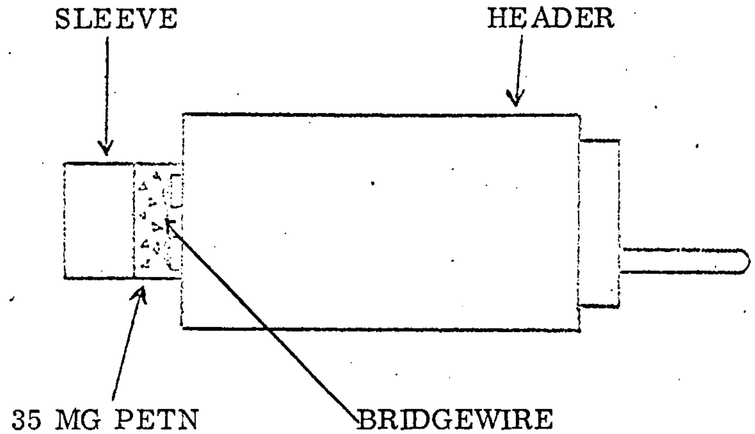
EBW Header Subassembly

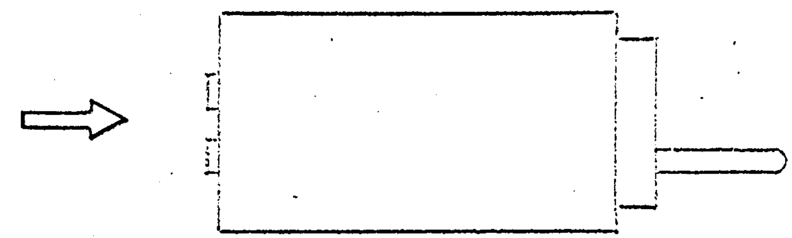
Figure 11



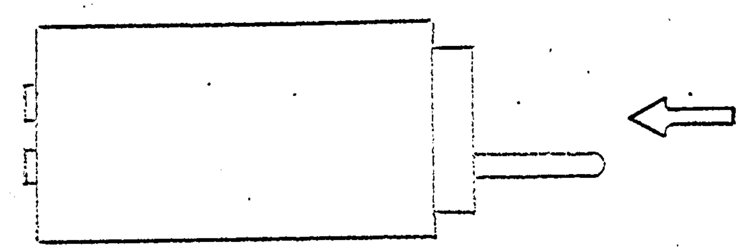
SINGLE PIECE PIN HEADER

FIGURE 12

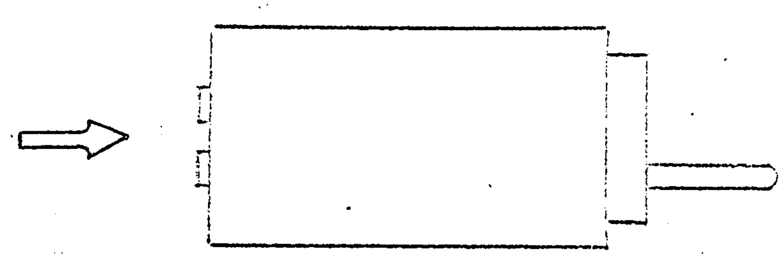




a. Three multi pin no leak. Three single pin no leak.



b. One multi pin leaker. Three single pin leakers.



c. One multi pin leaker. Two single pin leakers.

FIGURE 13

that is performed after the ceramic is completely formed and fired. Positioning of the countersink cannot be done on an individual basis and therefore seems to vary from unit to unit relative to the position of the through holes. It is concluded that a multiple piece pin is required whether it be two piece or three piece. Since the three piece pin affords the use of molybdenum to allow for a compressive ceramic seal, it is considered the best suited for the EBW Pressure Cartridge. In addition, the production yield of the three piece pin should be high considering the last group of twelve parts brazed produced ten headers without leak to 5,400 psig nitrogen pressure test.

4.4 EBW PRESSURE CARTRIDGE FABRICATION

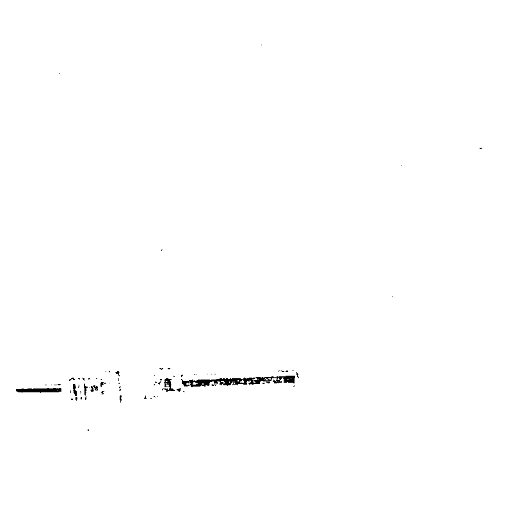
The program has been delayed due to slippage of parts delivery from vendors. The original vendor on the metal parts failed to deliver as scheduled and was cancelled. A new vendor was selected. Metal parts for the gap pin were quickly fabricated, but the metal body parts were held up due to higher priority parts manufacture by the vendor. These metal body parts are now in the last stages of fabrication and will be available for brazing and explosive loading by 1 August.

A local ceramics vendor was due to deliver gap insulators and header insulators by the middle of April. The gap insulators were delivered and are in process. The vendor has not been able to fabricate the header insulator. When molding the ceramics, large voids are present; when pressing the ceramics, cracks appear during the grinding operation.

The ceramics required for Phase IV of the program were ordered during this period from the original ceramics vendor as long lead items. The gap insulators are on hand. The header insulator was scheduled for delivery on 1 June, but has slipped to late July. Upon delivery, these ceramics will be used for Phase III and additional parts ordered for Phase IV. When requested for an explanation as to the delay since these ceramics are basically identical to those delivered earlier for the special pin seal strength test, the vendor claimed that new tooling was required for production since the earlier parts were fabricated in the prototype shop with temporary tooling. The delay was therefore attributable to receipt of satisfactory tooling from their vendor.

4.4.1 Spark Gap Pin Fabrication

During this period work has been progressing on fabrication of the gap pin as shown in Figure 14. Most gaps when assembled have ranged between approximately 750 volts to 1000 volts in static breakdown, and on an individual basis



Spark Gap Pin

FIGURE 14

the breakdown has varied no more than ± 50 volts. Two problems have been encountered in assembly. These are (1) yield of sealed gap pins has been extremely low with only three sealed out of the first thirty assembled, and (2) approximately one third of the gaps shorted due to braze material in the gap area. The units were assembled using two fixtures, one as a base to hold as many as 48 parts in an upright position and the other as a weight to force the parts together as the braze material liquifies. The braze material is in the form of a ring placed between the ceramic insulator and the anode and cathode caps as shown in Figure 15. It has been suggested that the weight of the top fixture is too great causing the liquid braze material to splash as it drops into place. As a result a braze material in paint form was procured to attempt brazing with the parts fully assembled. A total of six parts were tried and all ended in failure. The braze material did not appear to wet the nickel plated surfaces and the bond was capable of being pulled apart by hand. Another fix as suggested by NASA to be tried will be sectioning of the top fixture so as to provide a weight on only four parts at one time.

The basic seal problem may be related to the ceramic itself.

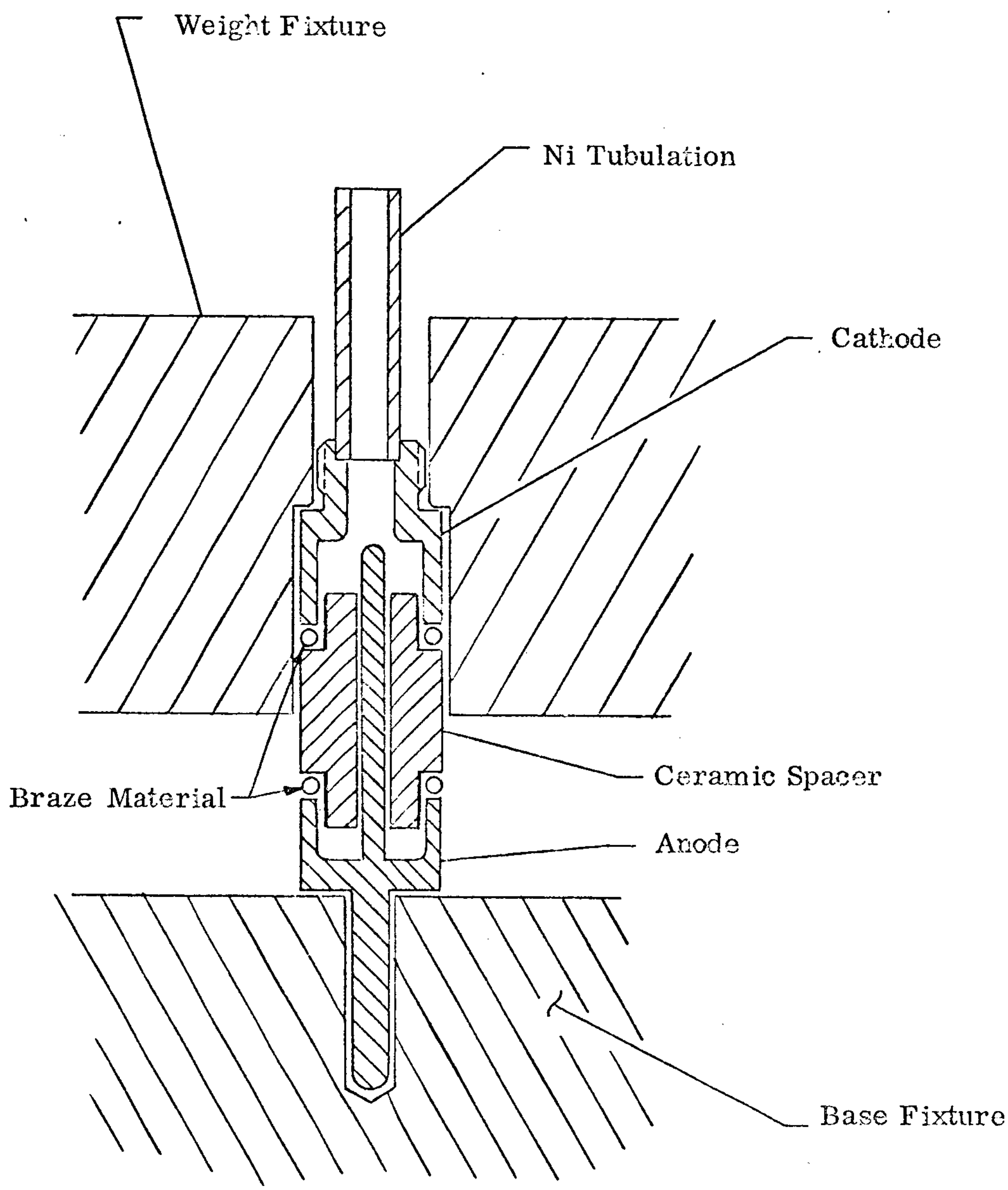

Weight Fixture
Ni Tubulation
Cathode
Ceramic Spacer
Braze Material
Anode
Base Fixture

FIGURE 15

A test will be performed to make this determination. If this is true, the ceramics on hand for Phase IV will be used for the Phase III parts since there is a history of successfully brazing that particular type ceramic.

4.4.2 Header Fabrication

Those headers not used during the pin seal strength test will be utilized to verify the body braze as soon as the body parts are available. This is presently scheduled for the last week in July.

4.5 PHASE III PROGRAM PLAN

The Phase III Program Plan updated is shown in Figure 16. As can be seen parts procurement has slipped at least one more week. This may affect the scheduled completion date. The Phase III program requires assembly of pressure cartridges, additional safety tests and the Development Test Program prior to completion.

5.0 PHASE IV - QUALIFICATION PROGRAM

Phase IV calls for fabrication of 200 EBW Pressure Cartridges plus an acceptance test quantity. In a recent meeting with NASA, a Qualification Test Program was received. The major problems to be encountered in the total program are anticipated during Phase III development, so that Phase IV can be considered verification of the development program.

HI-SHEAR CORP. – PROGRAM PLAN

CUSTOMER: NASA
RFQ NO.: 7-13-01802
P.O. NO.: NAS 8-20724 Phase III

PREPARED BY: L. Giattino
APPROVED BY:
DATE: 7/11/68

PAGE 1 OF 1

REVISION A

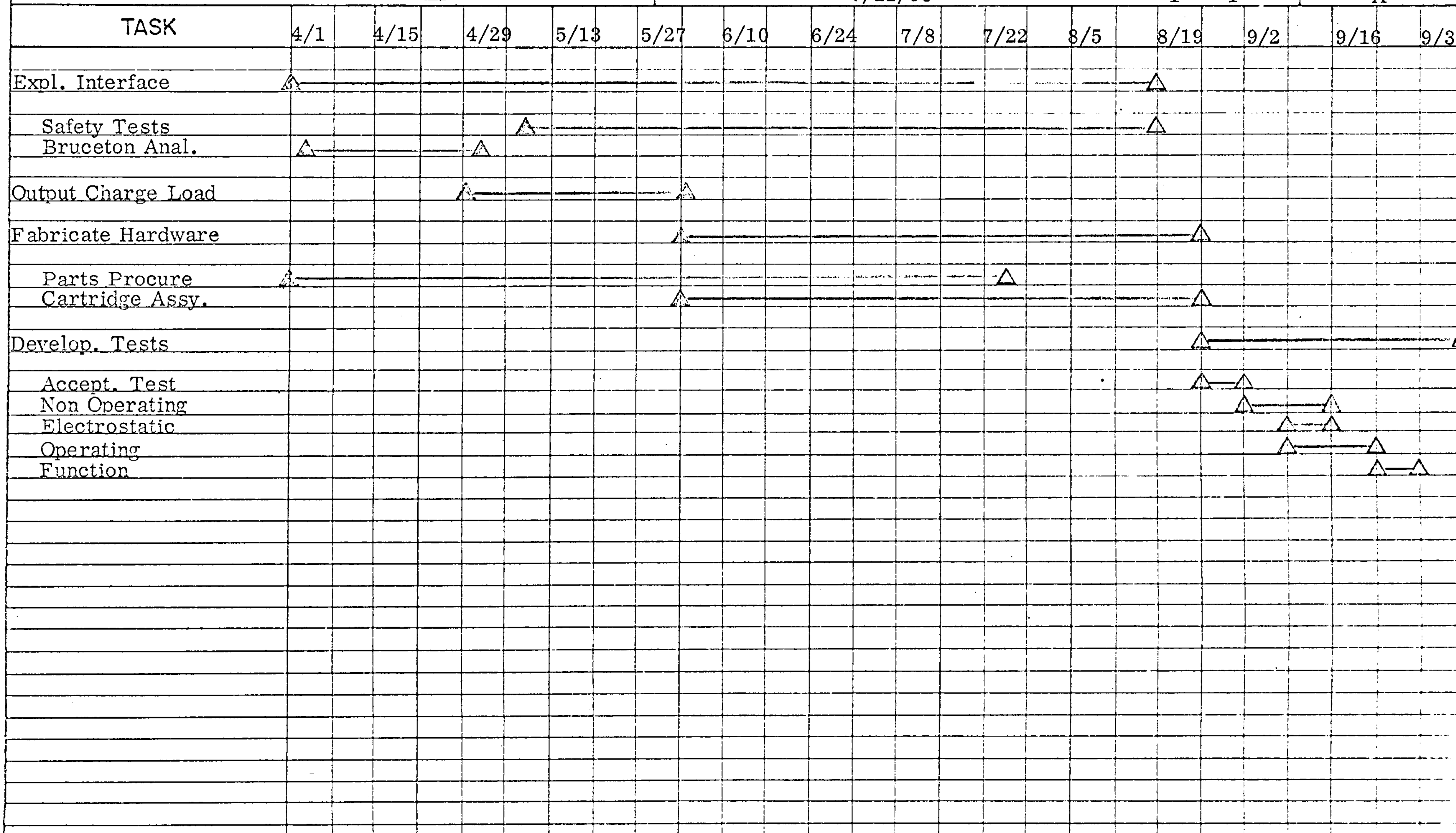


FIGURE 16

APPENDIX A

EXPERIMENTAL EBW PRESSURE CARTRIDGE THERMAL CYCLING TEST

Testing Sequence

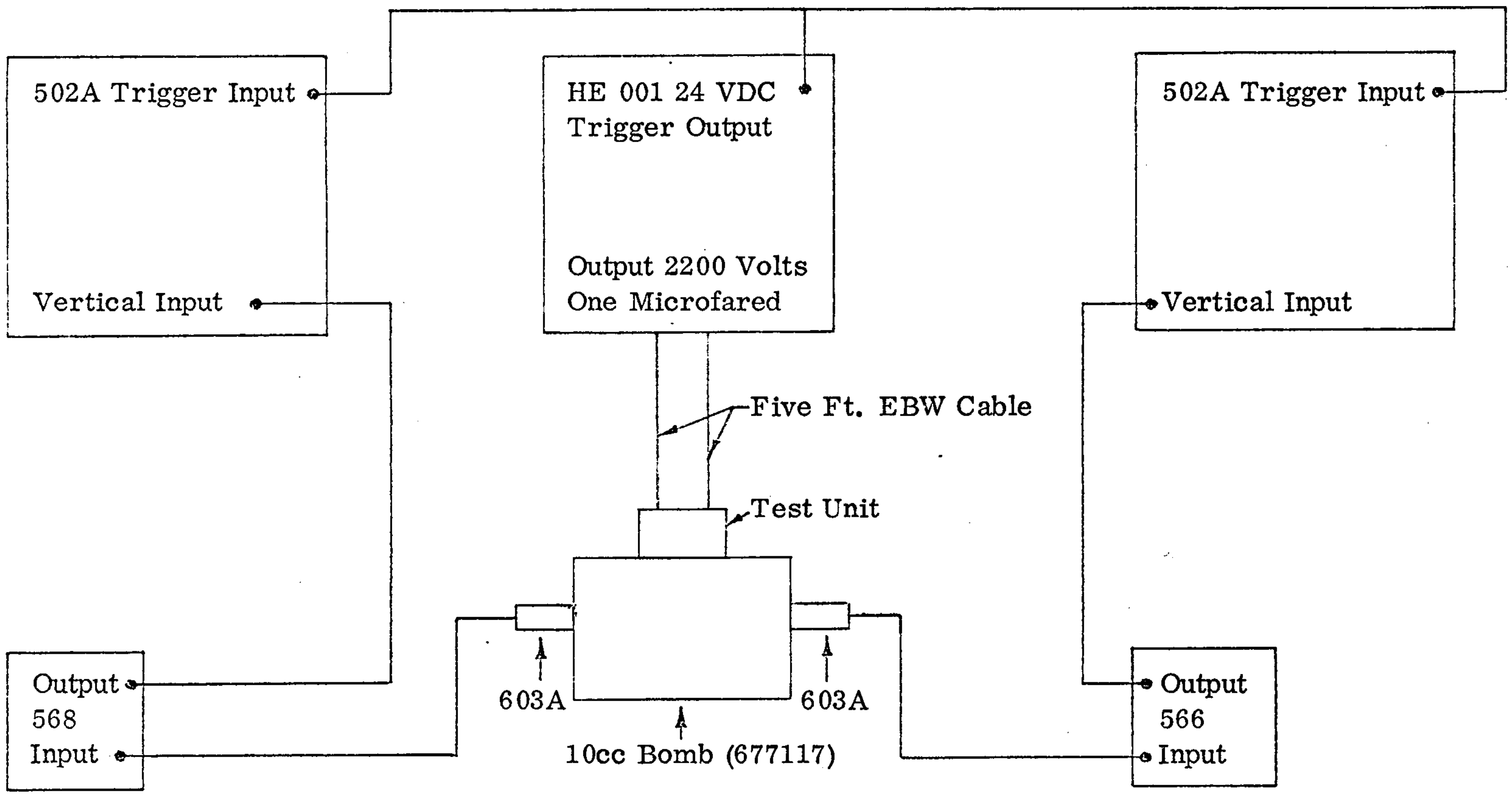
1.0 Two units (S/N 000436, 001545) were fired in a 10 cc closed bomb at +75°F without prior temperature conditioning.

2.0 Four units (S/N 000293, 000402, 000543, 2K-24709) were placed in a temperature cabinet stabilized at -300°F.

3.0 After two hours, the four units were transfered to a temperature cabinet stabilized at +390°F.

4.0 After two hours, two units (S/N 000402, 2K-24209) were removed from the temperature cabinet and immediately fired (maximum time out of temp prior to firing less than 30 seconds) in a 10 cc closed bomb, the other two units (S/N 000293, 000543) were placed in the temperature cabinet stabilized at -300°F.

5.0 After two hours in the temperature cabinet at -300°F, units S/N 000293 and 000543 were removed and fired immediately in a ten cc closed bomb.



Oscilloscope Trigger Circuit Control Settings:
- Slope
- Ext. DC Source
- Triggering Level 45° Clockwise from zero point.

Pressure vs. Time Settings:
- As required.

INSTRUMENTATION BLOCK DIAGRAM

INSTRUMENTATION LIST

Tektronix 502A Oscilloscope S/N 009610

Tektronix 502A Oscilloscope S/N 023360

Kistler 603A Pressure Transducer S/N 686

Kistler 603A Pressure Transducer S/N 625

Kistler 566 Charge Amplifier S/N 1709

Kistler 568 Charge Amplifier S/N 344

Hi-Shear HE 001 EBW Initiator Command Module S/N 001

Hi-Shear 10 cc Closed Bomb Drawing Number 677117 S/N 123

Hi-Shear Closed Bomb Cap Drawing Number 677119-003 S/N 114

Hi-Shear Closed Bomb Cap Drawing Number 67119-003 S/N 97 hi-shear CORPORATION

TEST DATA SHEET

Test Facility: HI SHEAR CORP. ORDNANCE TEST LABORATORY

Test Operator: G. MOORE, P. HULL

Specimen Description: EXPERIMENTAL E.B.W. POWER CARTRIDGE

Date Started: 11-15-67

Date Completed: 11-15-67

Type of Test: TEMPERATURE SHOCK AND FUNCTIONAL TESTS PER ENG. TEST REQUEST NO. EX 67-038

Lot No. 13-01802

CARTRIDGE S/N	TIME AT -300°F (HRS)	TIME AT +390°F (HRS)	TIME AT -300°F (HRS)	*FIRING VOLTAGE (VOLTS)	IGNITION TIME (MSEC)	PRESSURE RISE TIME (MSEC)	PEAK PRESSURE (PSIG)
000436	∅	∅	∅	2200	NOT OBTAINED SEE NOTE 1		
001546	∅	∅	∅	2200	0.2	0.2	650
000402	2	2	∅	2200	0.2	0.2	625
2K-24709	2	2	∅	2200	2.8	0.2	560
000293	2	2	2	2200	0.4	0.4	625
000543	2	2	2	2200	0.4	0.5	590

NOTE 1: OSCILLOSCOPES FAILED TO TRIGGER PROPERLY DUE TO IMPROPER TRIGGER CIRCUIT CONTROL SETTINGS

* DISCHARGE OF 1.0 μFD CAPACITOR THROUGH A 6 FT. E.B.W. FIRING CABLE

Remarks:

Witness By:
Hi-Shear

P. Moore Hull

FORM 4-768 REV. 8-60